REPORT

BY

PROFESSOR ANDERSON,

IN RELATION TO THE

SEWAGE OF GLASGOW,

UNDER THE REMIT MADE TO HIM AND

MESSRS. BATEMAN & BAZALGETTE,

BY MINUTES OF THE JOINT COMMITTEES OF THE MAGISTRATES AND COUNCIL
OF GLASGOW; THE CLYDE TRUSTEES, AND THE BOARD OF POLICE,
DATED THE 9TH AND 30TH AUGUST, AND 2ND OCTOBER, 1867.

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REPORT

ON THE COMPOSITION AND MODE OF UTILIZING THE SEWAGE OF GLASGOW, BY THOMAS ANDERSON, M.D., F.R.S.E.

The object of the Report which I have now the honour of presenting has been to obtain some definite information regarding the chemical composition of the sewage of Glasgow, and the mode in which it can be most advantageously utilized. Although the general composition of the sewage of towns is now sufficiently well known, several questions have been raised with special reference to that of Glasgow, to which I have particularly directed my attention. Among the most important of these are the degree of dilution and the presence of different kinds of manufacturing refuse, some of which, it has been supposed, may be injurious to plant life, and so render it useless for purposes of irrigation.

In order to solve these questions, it was necessary to commence with a series of analyses of the sewage waters of Glasgow, arranged on such a plan as to give some general idea of its composition. To obtain an accurate average of its composition is at the present moment impossible; for this can only be done when the whole sewage of a town is collected in one great tank from which samples can be drawn, and even then much labour is necessary in order to obtain a fair average.

As no means of doing this exists, the only course open to me was to proceed with the analysis of the water from individual sewers, and use the information so as to enable me to form some estimate of the composition of the whole. To do this accurately, an estimate of the average flow of water down each sewer would have been necessary, and to obtain it, an elaborate, long-continued, and costly gauging of the sewers would be required. In the absence of this, all that could be done was to collect the water from the sewers in such a manner as to get a daily average of each. In doing this, I aimed in the first instance at obtaining the sewage during dry weather; but after a long delay waiting for a favourable time, I was compelled to proceed with the collection of the samples during weather which was showery, and though no samples were collected during rain, the whole must be looked upon as containing the rainfall. From each sewer twenty-four samples were taken at intervals of an hour, and the whole of these being well mixed together, a portion of this mixture formed the actual sample analysed. My first intention was to have analysed the water from every sewer which flows into the river, but in the course of the investigation it became evident that this would be unnecessary. Many of the sewers are of small size, often draining a single street; and after a number of these had been analysed, it was found that their composition was so nearly alike that they might be fairly taken as the representatives of a class. In place, therefore, of proceeding with a large number of such analyses, which would have added little to our knowledge, I made a selection of the larger and more important sewers only. In each analysis the quantities of matters in suspension and solution re separately determined, but the complete analysis was made the entire sewage, containing both the matters in solution and pension. The results are contained in the following tables, in ich the results are expressed in grains per imperial gallon :—

	1.	2.	3.	4.	5.
	PINKSTON BURN.		Hydepark Street.	Washington Street.	Brown, Carrick, and M'Alpine Streets.
	I.	II.			
ATTERS IN SUSPENSION.					
organic Matter, . .	4·96	8·78	5·60	11·68	7·76
ganic Matter, . .	18·64	14·92	2·16	4·72	9·76
tal Suspended Matter,	23·60	23·70	7·76	16·40	17·52
OMPLETE ANALYSIS OF TOTAL SOLIDS, INCLUDING SUSPENDED MATTER.					
loride of Sodium, .	9·88	9·22	3·34	1·61	9·25
phate of Soda, . .	1·49	6·78	...	1·81	...
phate of Potash, .	4·66	...	1·24	...	3·29
bonate of Potash, .	...	2·99	...	1·32	...
osphate of Lime, .	3·77	4·18	0·77	1·39	1·81
phate of Lime, . .	8·08	...	1·93	...	...
bonate of Lime, .	...	7·99	2·17	4·52	3·52
phate of Magnesia, .	4·03	...	...	...	...
bonate of Magnesia,	1·44	3·73	1·08	1·28	0·88
oxide of Iron, . .	0·87	0·86	1·36	0·73	0·40
umina, ...	4·01	...	1·19	1·44	1·21
oluble Matter, . .	1·80	3·28	3·04	8·54	5·14
ganic Matter, . .	36·57	26·29	2·86	7·36	12·10
otal Solids, . . .	76·60	65·32	17·98	30·00	37·60
osphoric Acid in the Phosphate of ime, ...	1·73	1·91	0·33	...	0·83
rogen, ...	1·28	1·10	0·32	...	0·46
ıal Ammonia, . .	1·56	1·34	0·39	...	0·56

	6. James Watt Street.	7. York Street.	8. Robertson Street.	9. Oswald Street.	10. Jamaica Street.
MATTERS IN SUSPENSION.					
Inorganic Matters, . .	18·24	5·60	19·20	6·16	1·92
Organic Matters, . .	9·37	7·44	11·12	9·52	4·00
Total Suspended Matter,	27·61	13·04	30·32	15·68	5·92
COMPLETE ANALYSIS OF TOTAL SOLIDS, INCLUDING SUSPENDED MATTER.					
Chloride of Sodium, .	11·45	10·79	42·19	37·48	4·61
Sulphate of Soda, . .	0·55	...	...	...	0·89
Sulphate of Potash, .	2·39	3·05	3·41	1·78	2·67
Carbonate of Potash, .	...	...	...	...	...
Phosphate of Lime, .	2·07	1·90	3·57	2·22	1·39
Sulphate of Lime, . .	3·45	0·88	3·24	1·43	...
Carbonate of Lime, .	4·18	1·76	2·73	...	3·40
Sulphate of Magnesia, .	...	...	...	1·20	...
Carbonate of Magnesia,	2·26	1·57	1·13	...	1·64
Peroxide of Iron, . .	1·28	0·33	1·75	0·57	0·49
Alumina, ...	0·97	...	1·24	2·15	...
Insoluble Matter, . .	12·08	3·08	12·60	3·12	1·20
Organic Matter, . .	11·50	11·92	18·34	11·65	5·71
Total Solids, . . .	52·18	30·00	90·20	61·60	22·00
Phosphoric Acid in the Phosphate of Lime, ...	0·95	0·88	1·65	1·02	0·63
Nitrogen, ...	0·61	0·42	0·77	0·69	0·24
Ammonia, ...	0·75	0·57	0·94	0·84	0·30

	11.	12.	13.	14.	15.
	Dixon Street.	Maxwell Street.	Stockwell Street.	Molendinar Burn.	Main Street, Bridgeton.
MATTERS IN SUSPENSION.					
Inorganic Matter, .	9·92	6·39	4·48	5·04	3·44
Organic Matter, . .	6·72	6·09	5·92	6·08	7·84
Total Suspended Matter,	16·64	12·48	10·40	11·12	11·28
COMPLETE ANALYSIS OF TOTAL SOLIDS, INCLUDING SUSPENDED MATTER.					
Chloride of Sodium, .	6·90	19·67	15·12	9·95	...
Sulphate of Soda, . .	...	...	...	7·01	9·87
Chloride of Potassium,	...	2·67	1·31	...	...
Sulphate of Potash, .	3·02	...	1·09	2·70	1·98
Chloride of Calcium, .	315·48	...	...	...	...
Chloride of Manganese,	33·78	...	...	1·96	...
Phosphate of Lime, .	trace	1·86	2·08	0·55	1·11
Sulphate of Lime, . .	...	6·74	2·24	4·55	8·45
Carbonate of Lime, .	...	1·76	2·10	11·67	...
Sulphate of Magnesia, .	6·51	...	...	7·23	3·46
Carbonate of Magnesia,	...	2·19	1·34	...	...
Peroxide of Iron, . .	2·40	0·06	0·72	1·14	0·49
Alumina, ...	...		...	0·53	...
Insoluble Matter, . .	4·53	3·08	2·38	1·26	3·60
Sulphate of Ammonia,	...	...	...	...	24·07
Organic Matter, . .	17·43	10·93	7·02	6·69	26·61
Total Solids, . . .	390·05	48·96	35·40	54·94	79·64
Phosphoric Acid in the Phosphate of Lime,	trace	0·85	0·94	0·25	0·51
Nitrogen, ...	trace	0·39	0·46	0·38	...
Equal Ammonia, . . .	trace	0·48	0·56	0·42	6·62

	16.	17.	18.	19.	20.
	Clyde Street, Anderston.	South Portland Street.	Crown Street.	West Street.	Paisley Road.
MATTERS IN SUSPENSION.					
Inorganic Matter, . .	12·80	5·28	2·96	10·72	6·01
Organic Matter, . .	6·80	17·76	4·08	4·56	4·39
Total Suspended Matter,	19·60	23·04	7·04	15·28	10·40
COMPLETE ANALYSIS OF TOTAL SOLIDS, INCLUDING SUSPENDED MATTER.					
Chloride of Sodium, .	3·30	7·63	6·20	4·28	8·24
Sulphate of Soda, . .	3·90	0·44	0·73	1·07	...
Sulphate of Potash, .	...	...	2·05	1·70	1·87
Carbonate of Soda, . .	...	2·50	...	...	...
Carbonate of Potash, .	1·58	3·67	...	...	...
Phosphate of Lime, .	0·83	2·64	1·11	0·27	1·39
Sulphate of Lime, . .	...	...	1·88	1·08	9·18
Carbonate of Lime, .	6·56	4·52	4·01	4·48	1·64
Carbonate of Magnesia,	1·72	0·36	2·03	1·95	3·02
Peroxide of Iron, . .	1·23	0·27	0·34	1·09	0·59
Alumina, ...	0·78	...	0·31	1·08	0·50
Insoluble Matters, . .	10·42	3·20	1·68	6·38	3·78
Organic Matter, . .	9·68	29·68	9·30	5·90	9·95
Total Solids, . . .	40·00	54·91	29·64	29·28	40·16
Phosphoric Acid in the Phosphate of Lime, ...	0·38	1·20	0·51	0·12	0·63
Nitrogen, ...	0·43	1·31	0·29	0·12	0·38
Equal Ammonia, . .	0·53	1·59	0·37	0·14	0·46

	21.	22.
	Messrs. Higginbotham's Works.	Messrs. Monteith & Co.'s Works.
MATTERS IN SUSPENSION.		
Inorganic Matter,	4·08	2·96
Organic Matter,	27·68	13·12
Total Suspended Matter,	31·76	16·08
COMPLETE ANALYSIS OF TOTAL SOLIDS, INCLUDING SUSPENDED MATTER.		
Chloride of Sodium,	3·05	3·27
Chloride of Potassium,	...	0·46
Sulphate of Soda,	1·59	...
Sulphate of Potash,	1·66	2·99
Phosphate of Lime,	1·80	0·66
Sulphate of Lime,	4·03	3·24
Carbonate of Lime,	4·80	5·05
Carbonate of Magnesia,	1·62	1·79
Peroxide of Iron,	0·72	0·72
Alumina,	0·12	0·69
Insoluble Matter,	1·76	1·76
Organic Matter,	42·60	20·09
Total Solids,	63·74	40·72
Phosphoric Acid in the Phosphate of Lime,	0·82	0·30
Nitrogen,	1·45	0·39
Equal Ammonia,	1·77	0·48

The point which immediately attracts attention in relation to these analyses is the extreme degree of dilution of the sewage examined, which is far in excess of anything hitherto observed in any other town. In making a comparison, however, it must be borne in mind that it is dry weather sewage which has been most commonly examined, whereas that which I have analysed was collected during moist, though not absolutely wet, weather. Excluding, for the present, Nos. 11, 15, 21, and 22, in which manufacturing refuse forms too large a proportion to admit of their being compared with other sewage, and taking the quantity of ammonia as the standard of value, it appears that the largest quantity of that substance amounts to 1·59 grains per gallon, and the lowest to no more than 0·14, or about $\frac{1}{7}$ of a grain per gallon. It thus appears that some of the sewers of Glasgow yield a product ten times less valuable than others, and it also appears that in general the smaller sewers yield the least valuable sewage. The degree of dilution, in fact, must depend on a variety of circumstances, among which the thickness of the population of the district drained by any particular sewer is of great importance. It is obvious, indeed, that the larger the district, and the thinner the population drained, the greater must be the ratio of rainfall to true sewage water; and hence such analyses are of little use in fixing the average composition of Glasgow sewage, although they afford important data for determining the nature of its constituents.

The only town with which it is possible to make any comparison is that of Rugby, the sewage of which has been very carefully examined by a Parliamentary Commission. The sewage is there collected in one large tank, from which samples were taken for analysis at frequent intervals during a period of nearly three years, so that a very fair estimate may be formed both of its average composition and of the extremes within which it varied. From these analyses it appears that the average quantity of ammonia is 6·5 grains per gallon, and the minimum 2·5 grains. The best sample of the Glasgow sewage I had examined was therefore about four times as dilute as the average Rugby sewage, and the worst about eighteen times as dilute as the minimum of that town. Both the water supply and rainfall of Rugby are small compared with those of Glasgow; and hence it was to be anticipated that the former should be superior to the latter. But it cannot for a moment be supposed that the difference can be so great as my analyses appear to indicate.

With this impression, my first intention was to repeat the analyses of the sewers in dry weather; but, after mature consideration, I came to the conclusion that, though it might be possible in this way to approach nearer to the true average, there was no prospect of attaining it with any degree of accuracy without a number of analyses and an amount of delay altogether out of proportion to the object—the more especially as the same result could be better and more accurately attained by another method.

The composition of the excrementitious products is not so well known that the average yield per head of the population can be calculated; and, as the amount both of sewage water and rainfall are known, there is no difficulty in determining by calculation from these data the average composition of the sewage.

According to Messrs. Bateman and Bazalgette the sewage of Glasgow, independent of rainfall, amounts to 70 gallons a day per head of the population, which is equivalent to 119 tons per annum. The rainfall of Glasgow is about 38 inches yearly; and as every inch of rain falling on an acre of land weighs rather more than 100 tons, and the area of the city of Glasgow is 5,063 acres, there must fall upon it every year 19,239,000 tons of rain, all of which passes of by the sewers. Assuming the population at 500,000, this gives rather more than 38 tons of rain per head. The excrementitious matters from each head of the population must therefore be diluted with 152 tons, or say in round numbers 150 tons of water. The excrementitious products, when diluted to this extent, yield a sewage containing 2·60 grains of ammonia per gallon, and may be estimated as worth $\frac{2}{3}$ of a penny per ton.

A calculation such as this appears to me to give a far more accurate estimate of the average value of Glasgow sewage than can be obtained by even the most protracted series of analyses of the contents of individual sewers, and I am satisfied that it may be accepted as representing its true average composition. It is, then, manifestly a very dilute sewage, but its inferiority to that of other towns is not so great as might be supposed. The sewage of Rugby contains, on the average, according to the analyses already referred to, 6·5 grains of ammonia per gallon, and is therefore about two and a half times as valuable as that of Glasgow. As both the water supply and rainfall of Rugby are small, its sewage must be more concentrated than that of most towns. It is certainly more so than that of London, where the sewage and rainfall together amount to about 100 tons per head, and must therefore contain 4·41 grains of ammonia per gallon. From these data it appears that the sewage of Glasgow must be worth about two-thirds that of London; and this estimate, I am satisfied, may be accepted as a near approximation to the truth.

In fixing the value of the Glasgow sewage there is, however, one other point to be noticed, in regard to which doubts have been expressed. It has been asserted that its value is more or less completely neutralised by the presence of different kinds of manufacturing refuse, which it is supposed must be injurious to plant life, and that it is thereby rendered unfit for direct application to the soil by irrigation. The analyses already given lend no countenance to this view. In addition to the determination of the ordinary constituents of the sewage water, careful experiments were made in each case for the purpose of detecting any specially objectionable substances, but in no case were they found present. There is only one sewer the contents of which, if applied unmixed to the land, are in the least degree likely to prove injurious. This is the Dixon Street sewer, which contains large quantities of chloride of calcium and chloride of manganese. These substances are certainly of no use to the plant, and their abundant application would probably prove injurious; but if mixed with the general sewage of the town, I do not believe that any injury is to be apprehended from them. Any doubt on this point may, however, be solved by excluding this refuse from the general sewage. It has no manurial value; and, as in a sanitary point of view it is unobjectionable, it might continue to be discharged into the river, though it would be desirable that this should be done at a point below the harbour.

So far from the refuse matters from manufactories in general injuring the sewage for agricultural purposes, many of them are positively beneficial. A very striking illustration of this is offered by the sewage of Main Street, Bridgeton, which contained no less than 6·6 grains of ammonia per gallon, mostly in the state of sulphate, and which was undoubtedly refuse from the large coal-tar works in that neighbourhood. By this refuse, the contents of that sewer had been raised to a standard far above that of any other examined. The same thing applies, though in a less degree, to the refuse of distilleries, printworks, and many other manufactories. The spent waste contributes to the sewers the soluble nitrogenous matters, and salts of the malt and grain; and the same substances are obtained in the refuse of dyeworks; while the alum, chromate of potash, prussiate of potash, and other substances, add potash which is so valuable to the plant. On the whole, I am of opinion that manufacturing refuses enrich rather than impoverish the sewage; and as the estimate I have already made of the value of the sewage of Glasgow takes no account of these substances, I believe it will prove to be under rather than above the truth.

In all the observations I have made, I have founded on the quality of the sewage of Glasgow as it at present exists; but whatever method of disposing of it may be ultimately adopted, it can scarcely be doubted that some means of diminishing its quantity must be adopted. The rainfall, which amounts to nearly one-third of the whole matter passing through the sewers, may obviously be excluded; and Messrs. Bateman and Bazalgette are of opinion that the enormous waste of water may be considerably reduced. A large proportion of the refuse-water from manufactories may also be excluded. Much of it is only discoloured and rendered unsightly by use; and provided it contains no putrescible matter, it may be allowed to flow into the river without producing any injurious effects. By this means, I have no doubt, the value of the Glasgow sewage may be so increased as to enable it to bear comparison with that of any other large town.

It remains for me to express an opinion as to the method by which the sewage of Glasgow may be most advantageously utilized. The plans which have been proposed for the utilization of sewage are extremely numerous, but they may be divided into four classes:—1st, Dry processes; 2nd, Processes dependent on precipitation; 3rd, Processes dependent on the separation of the excrementitious matters from other refuse; 4th, Irrigation.

The first of these methods I think it unnecessary to consider; for, though some of them undoubtedly fulfil all that is required in a sanitary point of view, the cost of carrying them out on a large scale would, I am satisfied, prove extremely large; and, even supposing it possible to employ them with a reasonable chance of partially covering expenses, they involve such a revolution in the domestic habits of the population as to make it almost impossible to introduce them. As regards processes of precipitation, I have already, eleven years since, expressed an unfavourable opinion. That opinion was much criticised at the time; but it has been completely confirmed by the course of events. Several of the most feasible processes of the kind have been tried on a considerable scale, but all have proved failures; and this must be the inevitable result of a process which *must* be content to sacrifice the ammonia, in which at least three-fourths of the value of sewage depends.

A variety of processes have been proposed, which aim at separating the excrementitious matters from the general sewage, and subjecting the highly-concentrated matters thus obtained to a variety of manufacturing processes, by which they are to be converted into dry manures. Many of these processes are highly ingenious; but they are given to the public in so crude a state that it is difficult to form any estimate of the cost of carrying them out in practice. Independently of this, however, I am satisfied that any plan which contemplates a double set of sewers is likely to fail, owing to the amount of care and attention which it would require on the part of the public. Double sewers would require the use of a double set of vessels, in which the different kinds of refuse may be conveyed, each to their appropriate sewers; and I believe it would be found impossible to get the necessary precautions adopted. Servants would take the easiest way for themselves, and the refuse would be constantly poured into the wrong sewers.

There remains only, then, the method of irrigation, which I believe to be the only one likely to succeed in practice. It has already borne the test of experience, and at Edinburgh, Croydon, and other places, has proved eminently successful.

I think it unnecessary here to enter into any details on this matter, because the present state of the question has been very fully discussed by Messrs. Bateman and Bazalgette in their Report. With the opinions they have expressed I fully concur. I am satisfied, indeed, that the use of the sewage of Glasgow by irrigation would go far to cover the large expense of conveying it to a distance. To support any other plan in its present state, would be to advise the Corporation to embark in a commercial speculation of a very doubtful character, which might involve a very large useless expenditure.

THOMAS ANDERSON.

25th October, 1869.

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